VOLUME 80 SEPARATE No. 443

PROCEEDINGS

AMERICAN SOCIETY
OF
CIVIL ENGINEERS

MAY, 1954

CONCENTRATION OF COMBINED PRIMARY AND ACTIVATED SLUDGES IN SEPARATE THICKENING TANKS

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SANITARY ENGINEERING
DIVISION

{Discussion open until September 1, 1954}

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Printed in the United States of America

Headquarters of the Society
33 W. 39th St.
New York 18, N. Y.

PRICE $0.50 PER COPY

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This paper was published at 1745 S. State Street, Ann Arbor, Mich., by the American Society of Civil Engineers. Editorial and General Offices are at 33 West Thirty-ninth Street, New York 18, N. Y.

CONCENTRATION OF COMBINED PRIMARY AND ACTIVATED SLUDGES IN SEPARATE THICKENING TANKS

Wilbur N. Torpey,[1] M. ASCE

The operation of a sewage treatment plant results in the formation of sewage sludge which must be disposed of continuously. The expense of providing and operating sludge disposal facilities comprises a considerable portion of the overall treatment cost. These expenses depend upon the volume of sludge produced by the treatment process and are especially high at those plants employing secondary treatment. From an economic standpoint it is important that the volume of sludge to be disposed of be held to a minimum. A procedure for reducing the volumes of raw sewage sludges below those normally obtained, without incurring extra cost, can thus become the means for significant decreases in the cost of sewage treatment.

One source of sludge in a treatment plant is the primary settling tanks where a considerable portion of the solids are settled from the sewage. It is found in practice that in a mechanically cleaned tank, considerable difficulty is experienced in controlling the storage of solids at the floor of the tank in the so-called sludge blanket to obtain uniform sludge concentration. The usual result is the pumping of excessive volumes of primary sludge. This condition is often concealed by the apparently high concentrations of primary tank sludge obtained by common sampling procedures.

Where biological treatment follows primary sedimentation additional solids are removed from the sewage. These secondary solids are resistant to compaction because of their inherent biological structure, and consequently large volumes of dilute sludge are produced. This excess secondary sludge may be pumped to separate thickening tanks where the operation is controlled by adjusting the rate of withdrawal of sludge in relation to the depth of sludge blanket to secure optimum concentration consistent with the prevention of excessive loss of solids over the effluent weir.

A common practice outside of New York City is to send these secondary solids to the primary settling tanks for removal and compaction with the primary solids. The advantages of this procedure are the elimination of separate sludge thickening tanks and, under favorable conditions, some reduction in the net sludge volume. However, any deterioration in the settleability of the secondary solids, usually associated with secondary system overload, is reflected in an increasingly poor primary effluent, which further overloads the secondary process. Such a progressive deterioration could result in a breakdown of the secondary treatment process. New York City has therefore chosen to thicken biological sludges in tanks provided or adapted for that purpose.

Considering the facility of control when using separate thickening tanks, it appeared that a net reduction in sludge volume could be achieved by concurrently thickening both primary and secondary sludges in such tanks. It

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was therefore decided to investigate this procedure on a full plant scale. The Bowery Bay Plant was selected for this investigation since it was provided with the necessary facilities and could be adapted by a simple change in the piping. A further reason for conducting the investigation at this plant was to determine whether savings in digester capacity could be realized in the design of the plant extension which will soon triple the present capacity to 120 MGD.

The Bowery Bay Plant

The existing Bowery Bay Sewage Treatment Works is a step aeration activated sludge plant designed for a flow of 40 MGD. This plant employs 1.0 hour of primary sedimentation, followed by 2.5 hours of aeration and 1.7 hours of final sedimentation based on sewage flow plus 25% return sludge. During 1952, flow to the plant approximated the design rate and the sewage, which is predominantly domestic, contained about 150 ppm of suspended solids and 165 ppm of B.O.D. Sludge is digested in four tanks with a total capacity of 720,000 cu.ft., which provides slightly over 2 cu.ft. per capita of connected population. This plant has been operated using two different aeration processes, namely, step aeration and modified aeration.

When employing step aeration, the basis of the original design, primary effluent is admitted to the aeration tanks through the step gates in order to control the activated sludge concentration. The suspended solids concentration normally averages 2,500 ppm through the four passes of the aeration tank with the first pass containing about 4,000 ppm and with the concentration in the following passes decreasing until about 1,000 ppm is reached in the fourth pass. This method may be expected to require a like amount of air, produce an equal volume of excess activated sludge, and result in the same treatment efficiency, as does the conventional activated sludge process, while requiring about one-half the aerator volume.

The plant has also operated using the modified aeration process, otherwise known as high rate activated sludge. The flow pattern is similar to conventional activated sludge operation, wherein the primary effluent and return sludge flow together through the entire course of the aerator. The concentration of solids in the aeration tanks is considerably lower in this process, being in the order of 200 ppm of suspended solids. There is a significant decrease in treatment efficiency as compared to the step aeration activated sludge process. However, air requirements are reduced roughly by one-half and these modified aeration solids are more amenable to compaction.

In accordance with the original design, the secondary sludge has been concentrated in two circular thickening tanks, each 50′ in diameter, with sidewall water depth of 10 ft. and a conical bottom 6 ft. deep. Each tank is equipped with a two-arm picket fence thickening and sludge collecting mechanism of relatively rugged design. The mechanism is protected from damage resulting from torsional stress by an overload device on the drive motor. Incoming flow enters at the center of the tank, passes through a feed well and leaves by a peripheral triangular notched weir as shown in Figure 1. Two triplex sludge pumps were provided, one normal duty and one heavy duty.

The sludge discharge line from the primary sludge pumps to the digesters and the excess activated sludge line from the secondary treatment system to the thickening tanks are close to each other in an open gallery. In order to divert the primary solids to the thickening tanks, a pipe was installed connecting these two lines. Closing a valve on the primary sludge line at the digester gallery would then direct primary sludge into the excess sludge line

through which the combined sludges would flow for about 2 1/2 minutes prior to entering the thickening tank.

A valve was provided on the new connecting pipe so that original operation could be resumed. The sludge thickening operation prior to and following the change is illustrated in Figures 2-A and 2-B respectively.

These alterations were completed and the new facility placed in operation December 21, 1951. At that time the plant was operating on the modified aeration process. During 1951, primary sludge was directly pumped to the digesters from the primary settling tanks, while secondary sludge was separately thickened prior to digestion. About 36 MGD of sewage were treated and sludge pumping averaged 7800 cu.ft. per day of primary sludge and 5500 cu.ft. per day of thickened excess modified aeration sludge, a total pumpage of 13,300 cu.ft. per day. Relating the sludge produced to the volume of sewage treated, sludge pumpage averaged 220 cu.ft. of primary sludge and 150 cu.ft. of secondary sludge per million gallons of sewage treated or a total of 370 cu.ft. per million gallons.

Thickening of Combined Primary and Modified Aeration Sludge

Thickening of combined primary and secondary sludges was practiced throughout the year of 1952 while the modified aeration process was being used. The first four months constituted a trial period during which equipment was tested and procedures developed for handling the unexpectedly dense sludges obtained. During this period it became evident that the concentration of sludge was limited by mechanical difficulties of sludge handling. With sludge concentrations frequently over 15% solids and with discharge pressures above those anticipated in the design, the shear pins of the normal duty sludge pump failed. This pump was considered inadequate and later replaced by a heavy duty unit. The combination of heavy sludge, a discharge line 450 feet long together with a static lift of 20 feet, resulted in pressures as high as 100 p.s.i. at the pump, as compared to previous operating pressure of approximately 25 p.s.i. The location of the pump was such that a positive head of 11 feet was available on the suction side. However, because of the extremely viscous nature of the thickened sludge, the pump actually labored against a suction lift of as much as 15 feet. The total loss of head in 40 feet of 8" suction line was 26 feet under these conditions. It was therefore decided to pump the sludge below its maximum attainable concentration so as to maintain discharge pressures below 75 lbs. per sq. in. and to prevent negative heads at the pump inlet.

Pump control was by time clock, usually on a 30 minute cycle. The setting of the time clock was changed in accordance with the depth of sludge blanket, with the rate of sludge withdrawal being proportioned to the volume of the blanket. However, when discharge pressures were excessive or the head at the pump suction became negative, sludge was withdrawn continuously until safe conditions were restored.

At the start of the investigation, intermittent pumping of sludge from the primary settling tanks to the thickener was practiced. Cross-section sampling of the sludge blanket in the thickener with respect to solids concentration revealed deposition of alternate light and heavy layers of solids. In order to provide for more uniform concentration throughout the sludge blanket in the thickening tank, one primary sludge pump was operated continuously, the suction being changed between each of the three primary tanks hourly. Later the sludge blanket was sectioned and it was found that the alternate layers of light

and heavy sludge had practically been eliminated. Another reason for continuous primary sludge pumping was to maintain a steady flow of fresh primary solids to the thickener. On the other hand, some restraint was practiced in the primary pumpage in order to admit to the thickener a high ratio of aerobically treated liquor relative to the primary sludge flow. This operation of the primary pumps resulted in an average primary sludge having a 3.4% solids content.

During and following storms, it was found necessary to use two or three pumps on the primary settling tanks to prevent accumulation of silt carried into the plant via the combined sewer system, and consequent damage to the primary sludge collector mechanism. These silt loads, on entering the thickener, dropped rapidly near the center of the tanks and did not impose excessive torsional stress on the thickener mechanism, provided sludge was withdrawn to prevent accumulation. On several occasions, however, when pumping did not keep pace with the build-up of the sludge blanket, the mechanism stalled on overload, requiring that the standby thickener be placed in service, while the stalled mechanism was being freed.

Another effect of excessive accumulation of the sludge blanket was the rising of portions of dense sludge to the surface of the thickening tank, especially during warmer weather. During these times thickener effluent was returned to the wet well for resettling of this material. Furthermore, the sludge blanket was maintained at a lower level to minimize the amount of solids carried by the thickener effluent during the warmer weather. It is believed that a considerable portion of these rising solids may have originated in the truss work of the sludge collecting arms.

The process of thickening combined primary and modified aeration sludges was operated at the plant during the entire year of 1952. The results of this operation in the form of monthly averages of daily determinations are shown in Table I. Measurements with respect to volume and concentration were made on the materials entering and leaving the thickening tank. Unfortunately, there was so great a variation in the concentration of the mixed sludge admitted to the thickener that it could not be properly sampled.

The quantity of secondary solids was determined by measurement of the flow and concentration of the excess return sludge. The total suspended solids entering the thickener were calculated from measurements of solids leaving the thickener over the effluent weir and in the concentrated sludge. The ratio of secondary solids to the total was then calculated from these quantities. This ratio varied from 25% to 59% without apparent effect on the concentration of the thickened sludge. The "liquor ratio," defined as the secondary liquor flow divided by primary liquor flow, averaged 18.

The loading rates on the thickener varied mainly with the number of thickeners in service. For one tank operation, the solids loading rate, calculated on the basis of the solids in the sludge withdrawn from the tank, averaged 19 lbs. per sq. ft. per day. The liquid loading rate (overflow rate) averaged 1000 gallons per sq. ft. per day. In each case, the area was computed using the 50 ft. inside tank diameter. When two thickeners were employed, these loading rates were about halved. It was found that with one unit in service, sludge concentrations attained the maximum that could be pumped without difficulty, and the major portion of the period was devoted to such operation. However, when the liquid loading rates were high and the secondary solids exhibited poor settleability, the thickener effluent was adversely affected as shown in the results for February. There was some improvement in effluent quality with two units in service as against one, but even one thickener retained in

the concentrated sludge almost 90% of the solids admitted. Thickener effluent averaged about 5% of the sewage flow treated and varied in quality from 120 ppm to 420 ppm of suspended solids.

Sewage temperature also affected the effluent quality. Most favorable results were generally obtained at temperatures below 62°F., but the process operated quite well even when temperatures rose near 80°F. However, temperatures higher than 80°F. were not encountered for any appreciable period and some difficulty might be experienced in maintaining effluent quality under those conditions.

Another factor affecting the effluent quality was the quantity of sludge held in the thickener relative to the amount being removed, which is a measure of solids detention time. As is the case in the thickening of raw sludges, the sludge blankets must be lowered to maintain effluent quality at higher sludge temperatures.

From the beginning of this investigation high concentrations of the combined primary and modified aeration solids were obtained, averaging 14.4% for the month of January. Pumping difficulties and higher temperatures made it necessary to withdraw sludge at lower concentrations during the ensuing months. At the end of the year, progressive clogging of the discharge line to the digestion tanks increased pump pressure, especially during November and December, which required pumping at considerably lower concentrations than could have been attained. The sludge concentration for the entire year still averaged 11.2% solids and sludge pumpage was 133 cu.ft. per million gallons of sewage treated. This compares with a total pumpage of 370 cu.ft. per million gallons for the previous when conventional thickening was practiced, of which 150 cu.ft. per million gallons was excess sludge. The unit combined sludge pumpage for 1952 was essentially equal to the previously produced volume of excess modified aeration sludge alone. The thickening of combined primary and modified aeration solids thus resulted in a net saving of 64% of the previous year's unit volume of sludge, although the removal of suspended solids from the sewage remained the same.

These calculations are confirmed by comparison of digester gas production. During 1951, 13,300 cu.ft. of sludge per day produced 287,000 cu.ft. of gas per day, or 21.6 cu.ft. of gas per cu.ft. of sludge. During 1952, 5500 cu.ft. of sludge produced an average of 302,000 cu.ft. of gas per day, or 55 cu.ft. of gas per cu.ft. of sludge. By these measurements of the digester gas production, it is demonstrated that the concentration of the sludge in 1952 was 2.54 times that in 1951. The saving in volume would be $\frac{55 - 21.6}{55}$ or 61% on this basis, which agrees closely with the above reported saving of 64%.

This criterion, the quantity of gas generated per cu.ft. of sludge may also be used to check the solids concentration of the sludge entering a digester. Within comparable ranges of volatile matter, the gas production is proportional to the solids concentration. The digester solids loading rate may thus be determined more closely than by the unreliable and inaccurate sampling of sludge withdrawn from primary settling tanks.

In Table I is shown the Sludge Volume Ratio which is defined as the volume of sludge blanket divided by the daily volume of sludge pumped from the thickener. This relationship, which has the dimension of days, was used as a relative measure of the average solids detention time in the sludge blanket. In order to use the true solids detention time, an inventory of the weight of dry solids in the tank would have to be made frequently. The weight of dry solids so established divided by the rate of withdrawal of solids would constitute the

actual solids detention time. Such a method of control would be so laborious as to be impractical. Therefore, as a measure of solids detention time, the sludge volume ratio was used as a practical means of controlling the thickening process. The maximum S.V.R. used was governed by the capabilities of the various mechanical equipment and the thickener effluent quality that could be tolerated. For instance, during cold weather the S.V.R. was varied from 0.4 to 2.3 days. During the warmer weather when biological activity increased, resulting in gas formation, the range of S.V.R. was reduced to between 0.3 and 0.8 days.

If the S.V.R. were decreased below some critical value, a marked reduction in concentration would result as can be seen in Figure 3. Experiments were made to determine the rate of sludge consolidation during the first few hours of the thickening operation with a view toward approximating the critical S.V.R. It was found necessary to make these experiments on a plant scale, since attempts to study the thickening process on a laboratory scale were wholly unsuccessful. In these plant scale tests, a mixture of primary and modified aeration solids were concentrated both in a primary settling tank and a thickening tank. In all cases there was no sludge initially present. At hourly intervals samples of the concentrating sludge were withdrawn for analysis. In order that the sludge samples be representative it was necessary to first remove the contents of the suction line. The results of these tests are shown in Figure 4.

The curves in Figure 4 demonstrate that in each case there was a rapid, initial consolidation period of about 3 hours, followed by an abrupt decrease in the rate of consolidation. This is believed to have occurred when water no longer excaped freely from the sludge mass under the conditions of the tank and the sludge thereafter assumed gel-like properties. In order to maintain high concentrations of sludge, the thickening process must be controlled so that the solids to be thickened remain in the tanks for a long enough period to have attained the gel-like condition. For the primary and modified aeration solids in the thickening tank, there was required about 3 hours or 0.13 days to reach the gel-like state. On the basis of sectioning of the solids in the sludge blanket at various times and estimating the solids detention time, it is believed that the detention of 0.13 days actual thickening time stated above reasonably corresponds to an S.V.R. of 0.3 days. This sets the lower limit of operation for thickening combined primary and modified aeration sludges. Likewise, there is shown the superiority of thickening in a tank designed for that purpose when compared to the use of an ordinary settling tank.

An additional factor aiding in attaining a high concentration of combined sludges may be the condition of the liquor carrying the solids. It is known that when the liquor is septic or has become septic during thickening, the process is hindered and low concentrations of sludge result. Moreover, observations at other plants indicate the advantage of operating this thickening process in the presence of a preponderance of fresh secondary treated liquor to facilitate the attainment of high concentrations of sludge.

At the end of 1952, as stated previously, operation of the thickener became difficult because of high pump pressures resulting from an accumulation of grease on the walls of the discharge line to the digesters. During January and February of 1953, the process was repeatedly interrupted by excessive line pressures. Finally it became necessary to have the accumulated grease removed from the walls of the pipe.

Thickening of Combined Primary and Activated Sludge

In March 1953, operation was changed from the use of modified aeration process to the step aeration activated sludge process, and an activated sludge was built up during the first part of the month. It was fully expected that the activated solids would, as they have in the past, exhibit much greater resistance to consolidation than did the modified aeration solids. Thickening of combined primary and activated sludge was started on March 17th.

A change from the previous procedure was made on initiating this operation. It was disclosed after sectioning of the solids in the sludge blanket, that there was some evidence of activated sludge stratification between layers of mixed solids, even though one primary sludge pump was being operated continuously. Believing that a more uniform blanket might be beneficial to the control of the thickening of primary and activated sludges, two primary sludge pumps instead of one were placed in service increasing the flow of primary liquor from 75 gpm to 150 gpm. One pump operation was resumed in mid-July with no marked effect on thickener performance. Operating procedure for the thickening of activated sludge required the wasting of aerator effluent instead of return sludge as had been used in modified aeration sludge thickening. After five weeks of operation, it became evident, through the formation of high sludge blankets, that the thickening tank was becoming overloaded and the second tank was placed in operation April 24th. The sludge blanket was controlled without difficulty thereafter until July when a third unit, if available, would have been beneficial. It was also found that the abrupt changes in pressure that made pumping of thickened combined primary and modified aeration sludge difficult at times were not experienced during the activated sludge thickening operation.

The results of five and one-half months of thickening combined primary and activated sludges are presented in Table II. The liquor ratio during this period averaged 10. With two thickening tanks in service, the loading rates averaged about 12 lbs. of solids per sq.ft. per day and 500 gallons per sq.ft. per day liquid loading rate. Thickener effluent contained only 3 to 5% of the solids admitted for thickening, in a flow averaging about 5% of the daily sewage flow. The tanks were operated at a monthly average sludge volume ratio of 0.7 to 1.0 days.

The volume of the thickened combined primary and activated sludges started at 170 cu.ft. per million gallons of sewage treated in March and slowly increased until a volume of 390 cu.ft. per million gallons was reached in July. It is felt that during parts of July and August, the two thickeners were being overloaded with solids on a unit area basis and additional thickening area, if available, would have been beneficial in increasing sludge concentration. In this connection, previous operating experience with the thickening of activated sludge alone, indicated the inability of these two thickeners during the summer months, to handle the excess activated sludge. The concentration of the thickened combined sludge started at 9.0% solids in March and decreased to 4.6% in July and August.

In order to compare these results with those of activated sludge operation using separate thickening of excess sludge, Figure 5 was drawn. It shows the unit pumpages of excess activated sludge and total sludge for those months in 1947 and 1949 when the step aeration activated sludge process was employed, and the unit pumpage of combined sludge for March to August 1953. It can be seen that there is a considerable degree of coincidence between the volume of combined sludge pumped during 1953 with the volume of excess activated sludge

alone pumped in previous years for the same months. For all practical purposes, the unit volume of thickened combined primary and excess activated sludge pumped during 1953 equalled the unit volume of excess activated sludge alone pumped by conventional means. This resulted in a net saving in volume equal to the entire primary sludge pumpage. The average unit pumping for the period of combined thickening was 300 cu.ft. of sludge per million gallons of sewage treated. Primary sludge pumping in 1951 when a negligible quantity of digester solids were re-treated, averaged 220 cu.ft. per million gallons. The combined thickening on this basis had therefore effected an average reduction in net sludge volume of $\frac{(300 + 220) - 300}{520} = 42\%$.

The combined thickened primary and activated sludge differed from the combined thickened primary and modified aeration sludge in the pump pressure to sludge concentration relation. The dynamic head on the system, when pumping pure water to the digesters during a test, averaged 17 p.s.i. gage. Digester operating conditions made it impossible to fully define the pressure-concentration curve, especially at low concentrations. It is believed that the pressure rises very gradually from 17 p.s.i. until that sludge concentration is reached at which the sludge becomes gelatinous, and thereafter small increases in sludge concentration produces large increases in pressure. This gel-like concentration approximates 10% solids for the combined primary and modified aeration sludge since above that concentration pressures increased markedly. It may be noted that at about 10% solids there is also a marked change in the rate of solids concentration as shown in Figures #3 and #4. It appears that the basic structure of the sludge assumes gel-like properties at this concentration. In the case of the combined primary and activated sludge the gel-like concentration was not readably definable. The results shown in Table II indicate much higher pressures were required to pump a given concentration of combined primary and activated sludge than for primary and modified aeration sludge. The volatile content of the sludge, especially in the case of the combined primary and modified aeration sludges, affected these pressure characteristics considerably with the pressure rising as the volatile content increased at a given concentration.

Some Special Considerations

From the experience at Bowery Bay, it seems obvious that some special measures are required to handle the concentrated, viscous sludges produced by the combined thickening process. Fortunately, the plant was equipped with heavy duty circular thickeners, having torque overload protection for the collector mechanism together with a heavy duty triplex sludge pump operating on an automatic time clock, such equipment being well suited for this operation. The 450 feet long line from the pump to the digesters contributed to the rather high discharge pressures encountered at the pump, and it would have been beneficial if the thickeners had been located nearer the digesters. Similarly, the pump suction lines should be as short as practicable, with the pump located to afford the maximum positive head possible, while withdrawing sludge at a rate whereby not more than the available head will be lost by the sludge flowing to the pump.

In connection with the pumping of primary sludge for this 40 MGD plant the process requires a continuous flow of fresh, dilute sludge in rather small amounts (75 to 150 gpm). The plant primary sludge pumps were larger than required, but could be utilized at low speed by using less than one pump per primary tank and changing pump suctions frequently.

The ratio of secondary treated liquor to primary sludge liquor and the liquid detention are both affected by the rate at which secondary solids are wasted from the treatment process. It would have been desirable to have had provisions for supplementing the flow to the thickener with final effluent so that the rate of waste could have been adjusted to the aerator needs while still maintaining the desired liquid detention and liquor ratio.

With respect to loading rates, the process operated successfully on combined primary and modified aeration sludges at solids loading of over 20 lbs. per sq.ft. per day and overflow rates of 1000 gals. per sq.ft. per day. When operating on activated sludge, however, an average solids loading rate of 12 lbs. per sq.ft. per day in July and August of 1953 proved somewhat excessive in that the sludge withdrawal rate had to be significantly increased in order to maintain effluent quality. A rate of 8 lbs. per sq.ft. per day and an overflow rate of 600 gallons per sq.ft. per day would seem to be more reasonable loading rate limitations for hot weather operation with activated sludge.

Since thickening of combined primary and secondary sludges places a somewhat exacting load on the thickeners and its associated equipment, serious consideration should be given to providing standby equipment. If sludge disposal facilities are limited, in order to benefit from the reduced volume of sludge resulting from this process, it becomes particularly important to maintain continuous operation at high efficiency, especially when the thickened sludge undergoes digestion. This is borne out by the actual operation of the digester during this period, results of which have been presented before the Federation of Sewage and Industrial Wastes Association on October 14, 1953.

The volume of thickened combined sludge has been shown to be essentially equal to that of the secondary sludge thickened alone. In order to keep the volume of thickened primary and activated combined sludge at a minimum, it is apparent that the quantity of secondary solids should be kept at a minimum. From this reasoning, the use of more efficient primary tanks would be advantageous in further reducing sludge volume.

SUMMARY

At the Bowery Bay Plant in New York City, a process of concentrating combined primary and secondary sludges in separate thickening tanks has been operated from December 1951 through August 1953. This procedure, by which concentration of sludge may be completely separated from the sewage treatment processes, was carried out on a full plant scale using plant labor and the existing rugged equipment provided for conventional thickening.

During 1952, sewage treatment consisted of primary settling and modified aeration. The thickener was loaded at the rate of 19 lbs. of combined solids per sq. ft. per day and an overflow rate of 1000 gallons per sq.ft. per day. Sludge concentration averaged 11.2% total solids for the year while the volatile content of the solids averaged 74%. Pumpage averaged 133 cu.ft. of sludge per M.G. of sewage treated as compared to 370 cu.ft. per M.G. during conventional thickening practiced in 1951. Combined thickening thus reduced the unit volume of sludge to be digested by 64% of the volume formerly produced by conventional operation.

During March of 1953 the plant was placed on full activated sludge and thickening of primary and excess activated sludge started. For the five and one-half month period reported, loading rates averaged 12 lbs. of solids per sq.ft. per day at an overflow rate of 500 gallons per sq.ft. per day. Sludge

concentration varied from 9.0% solids in March to 4.6% solids in July and averaged 6.0%. Pumpage was at the rate of 300 cu.ft. per M.G. for the period, equivalent to the unit volume of activated sludge alone for previous years of operation. A net saving in sludge pumpage of 42% compared to previous experience was accomplished.

The process was controlled by using the concept of sludge volume ratio, defined as the volume of sludge blanket held in the thickener divided by the volume of sludge pumped per day from the thickener. In conjunction with this control, the depth of sludge blanket was kept low, thus aiding in the attainment of higher sludge concentrations. The upper limit of sludge concentration was determined, during colder weather, by the necessity of avoiding damage to the mechanical equipment involved. By using this method of thickening, advantage was taken of the inherent compactability of the primary solids to obtain a thickened combined sludge whose volume was essentially equivalent to the volume of excess sludge alone under previous conventional practice.

ACKNOWLEDGEMENTS

Thanks are extended to Mr. Hubert Becker, Jr., Senior Stationary Engineer Electric, in charge of the Bowery Bay Plant and his operating staff who cooperated in the solution of the many problems confronted during this extended plant scale investigation, and to Messrs. A. H. Chasick, Civil Engineer (Sanitary) and R. B. Wolf, Assistant Civil Engineer (Sanitary) for their aid in the preparation and presentation of this data.

The author is especially grateful for the assistance and advice of Mr. Richard H. Gould, Director of the Division of Sewage Disposal, in carrying out and evaluating this work.

Table I

RESULTS OF THICKENING OF COMBINED PRIMARY AND MODIFIED AERATION SLUDGES

	INFLUENT TO THICKENER								THICKENER EFFLUENT			SLUDGE WITHDRAWN FROM THICKENER						
				Calc.		No. of	Loading Rates				% S.S.	Thickened Sludge					Sludge	Pump
Date (1)	Flow MGD (2)	Temp. °F (3)	Calc. ss-ppm (4)	% second sol. of total (5)	Liquor Ratio (6)	Thickeners in Operation (7)	Solids Lbs. per sq.ft./day (8)	Liquid Gal. per sq.ft./day (9)	Susp. Sol. ppm (10)	BOD ppm (11)	Retained in Sludge (12)	% Sol. (13)	% Vol. (14)	Cu.ft. per day (15)	Cu.ft. per Mg of Sewage (16)	Lbs. per day (17)	Volume Ratio Days (18)	Disch. Press. psi (19)
1952																		
Jan.	2.0	57	2230	42	18						93	14.4	78.5	3700	90	34800		65
(1-14)						2	9	500	120	150							2.3	
(15-31)						1	17	1000	165	190							1.6	
Feb.	2.2	57	2210	59	20	1	17	1100	335[a]	275[a]	85[a]	12.2	78.7	4300	105	34400	1.2	53
Mar.	2.2	58	2590	31	20	2	11	550	135	170	95	12.5	73.1	5500	130	45000	0.9	50
Apr.	2.4	62	2420	44	21	2	11	600	195	220	92	11.9	69.7	5700[b]	150	44500	1.0	38
May	2.3	65	2540	45	20	1	22	1150	285	330	89	10.3	72.7	6400	150	43200	0.6	35
June	2.1	73	2600	37	19	1	20	1050	340	360	87	10.5	70.4	5800	120	39600	0.8	31
July	2.0	75	2880	30	18	1	21	1000	370	355	87	11.6	67.1	5500	130	41800	0.6	37
Aug.	1.3	76	3570	25	11	1	18	650	285	265	92	10.9	65.1	5000	110	35600	0.6	36
Sept.	2.0	74	2510	35	18	1	18	1000	320	360	87	10.2	74.2	5500	140	36500	0.5	37
Oct.	2.1	71	2450	36	19	1	18	1050	350	350	86	10.1	79.9	5600	160	36700	0.6	42
Nov.	1.8	68	3050	36	16	1	20	900	420	500	86	9.5	79.2	6300	170	39400	0.7	48[c]
Dec.	1.8	62	3160	32	16	1	22	900	220	195	93	10.1	79.3	6600	160	44100	0.6	54[c]
Ave.	2.0	—	2680	38	18	—	19 - 1T - 10 - 2T -	1000 550	285	295	89	11.2	74.0	5500	133	39600	0.8 - 1T - 1.4 - 2T -	

NOTES:

(a) Five days during February 1952 the thickened effluent deteriorated due to poor settling quality of modified aeration solids.

(b) Pumpage based on cubic feet to sea during April 1952. Digester seal readings not used because of foaming seals.

(c) Thickener pump discharge pressures increasing due to gradual clogging of discharge line. Complete stoppage occurred on January 8, 1953.

Col. 2 Flow to Thickener includes 75 gpm of primary liquor.

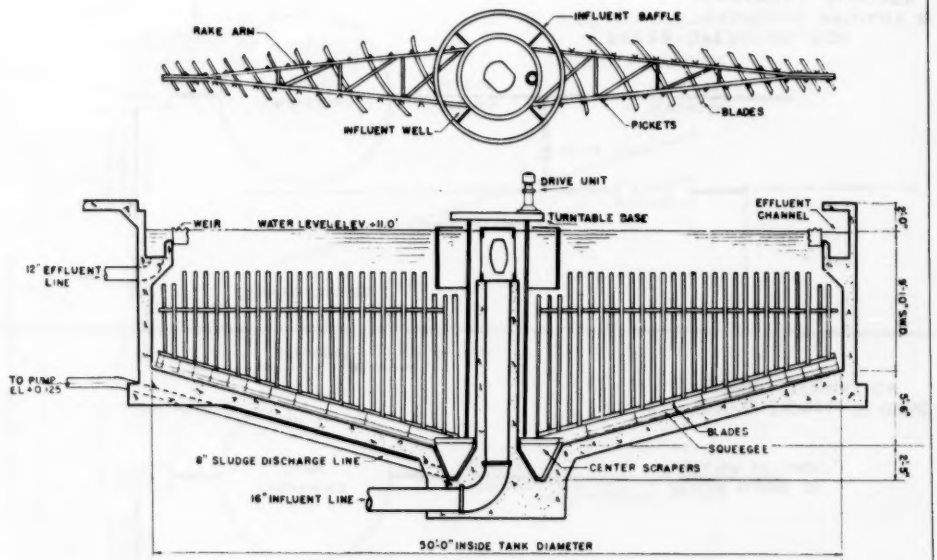
Table II

RESULTS OF THICKENING OF COMBINED PRIMARY AND EXCESS ACTIVATED SLUDGES

	INFLUENT TO THICKENER								THICKENER EFFLUENT			SLUDGE WITHDRAWN FROM THICKENER						
							Loading Rates					Thickened Sludge						
Date (1)	Flow MGD (2)	Temp. °F (3)	Calc. ss-ppm (4)	Calc. % second sol. of total (5)	Liquor Ratio (6)	No. of Thickeners in Operation (7)	Solids Lbs. per sq.ft./day (8)	Liquid Gal. per sq.ft./day (9)	Susp. Sol. ppm (10)	BOD ppm (11)	% S.S. Retained in Sludge (12)	% Sol. (13)	% Vol. (14)	Cu.ft. per day (15)	Cu. ft. per Mg of Sewage (16)	Lbs. per day (17)	Sludge Volume Ratio Days (18)	Pump Disch. Press. psi (19)
1953																		
March (17-31)	1.4	58	3530	34	6	1	20	700	175	130	95	9.0	71.6	6800	170	39200	0.8	52
April	1.8	61	2800	39	7	1	20	900	130	115	95	7.5	72.3	8300	200	40000	1.0	52
May	2.4	65	2430	47	10	2	12	600	95	75	96	6.1	69.4	12000	290	46700	0.7	38
June	2.0	73	2830	37	8	2	12	500	75	110	97	5.7	75.7	12600	310	46000	0.9	44
July	1.9	76	3140	35	11	2	12	475	170	120	95	4.6	71.1	15900	390	46800	0.8	30
Aug.	1.8	76	2880	34	17	2	11	450	75	75	97	4.6	71.2	14300	380	42000	0.9	32
Ave.	1.9	—	2880	38	10	—	20 - 1T - 12 - 2T -	800 500	115	100	96	6.0	71.9	12100	300	43800	0.9 - 1T - 0.8 - 2T -	

NOTES:

Col. 2 Flow to Thickener includes 150 gpm of primary liquor until July 18 when it was reduced to 75 gpm.



SCHEMATIC PLAN OF THICKENER MECHANISM
AND SECTION OF TANK

FIG. 1

BOWERY BAY STW

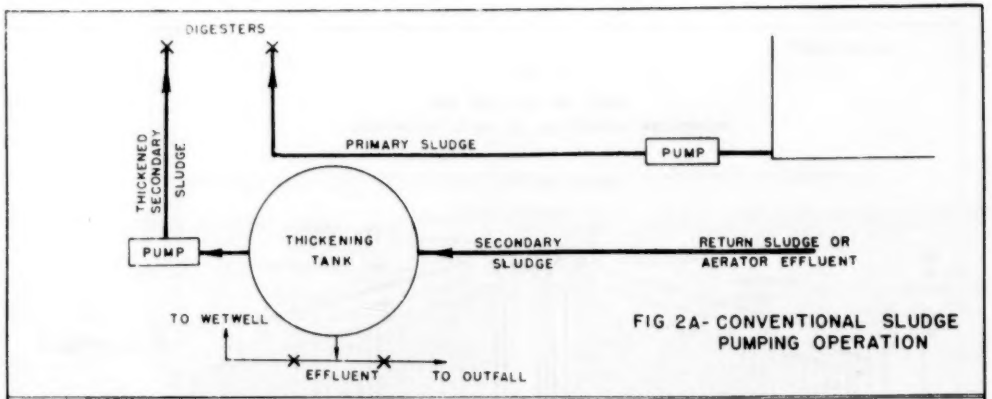


FIG 2A- CONVENTIONAL SLUDGE PUMPING OPERATION

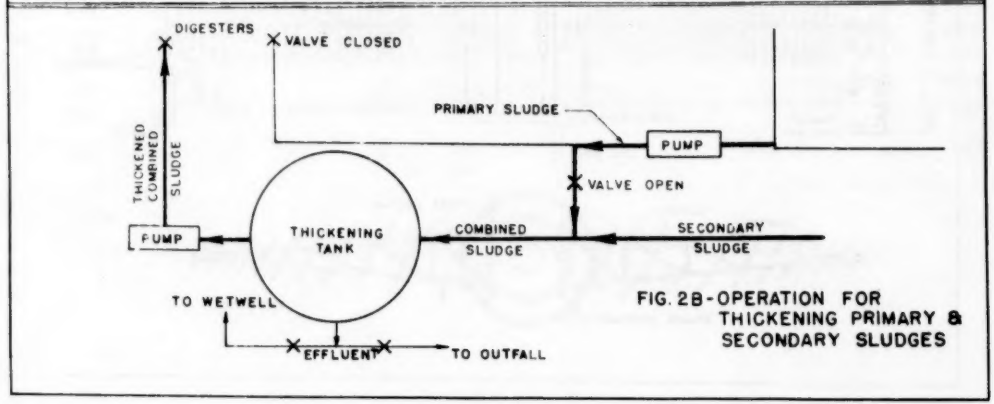
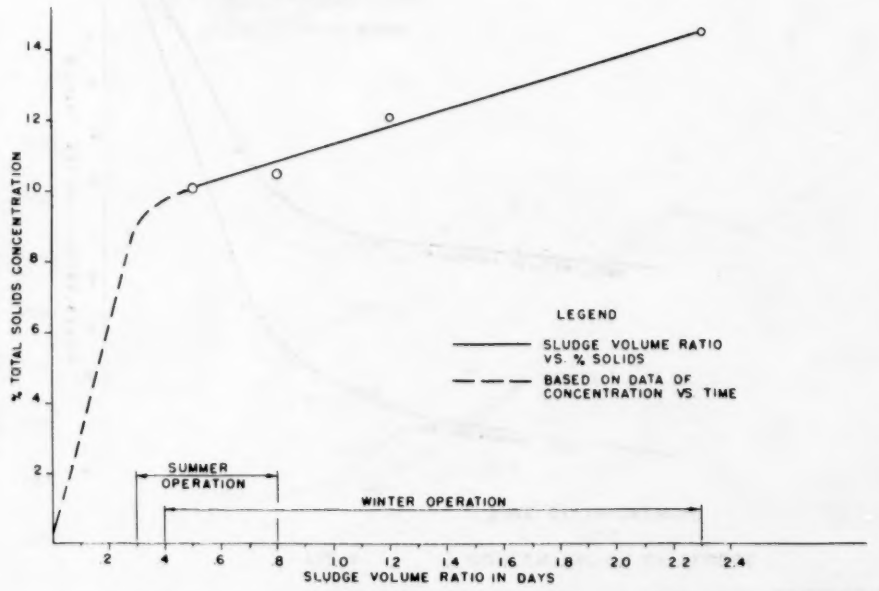


FIG. 2B-OPERATION FOR THICKENING PRIMARY & SECONDARY SLUDGES

FIG. 3
THICKENING OF COMBINED PRIMARY AND MODIFIED AERATION SLUDGES

SLUDGE VOLUME RATIO VS. CONCENTRATION



BOWERY BAY ST.W

FIG. 4 CONCENTRATION OF SLUDGE VS TIME OF THICKENING

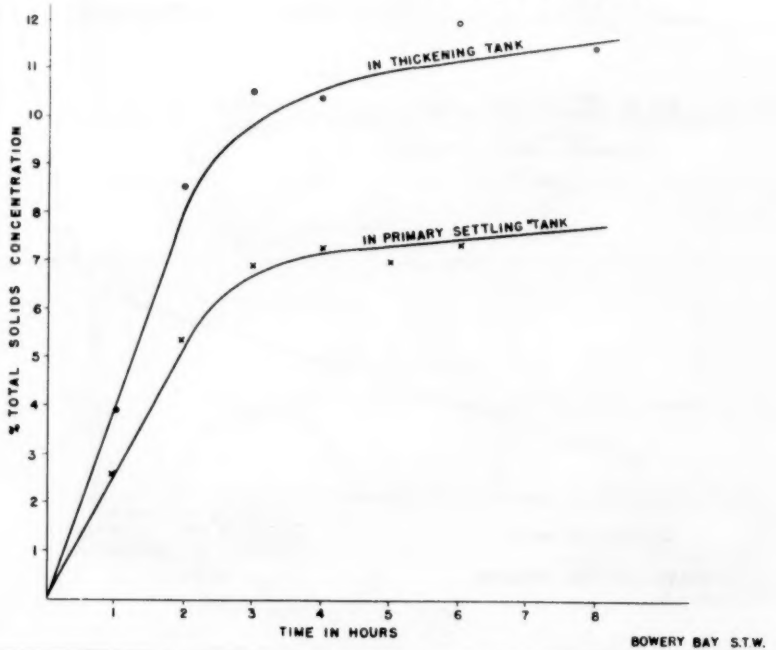
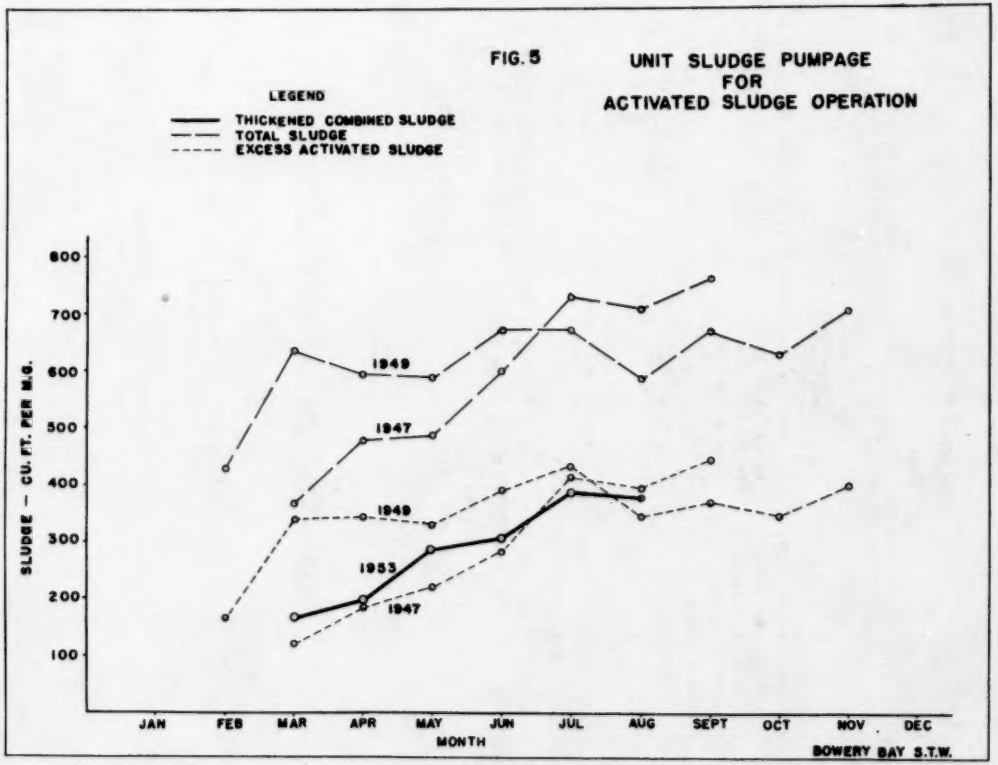


FIG. 5 UNIT SLUDGE PUMPAGE FOR ACTIVATED SLUDGE OPERATION



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